Meteorological Products and Examples

OVERVIEW

- Collecting and Archiving Data
- Current Conditions and Discussions
- Analysis of Forecast Models
- Critical Forecast Parameters
- Air Quality Forecasts

Collecting and Archiving Data (1 of 2)

- Reviewing past forecasts can improve future forecasts – What went wrong?
- A good data archive improves forecasts, reports, and presentations.
- Automatic collection of forecast images shortens forecast preparation time and focuses effort.

Collecting and Archiving Data (2 of 2)

Tools for collecting and archiving data

- Web utility programs can be used to mass download images of interest.
- A utility to loop images is also a great help analyzing forecast models.
- See “Helpful Utilities” in the Appendix.

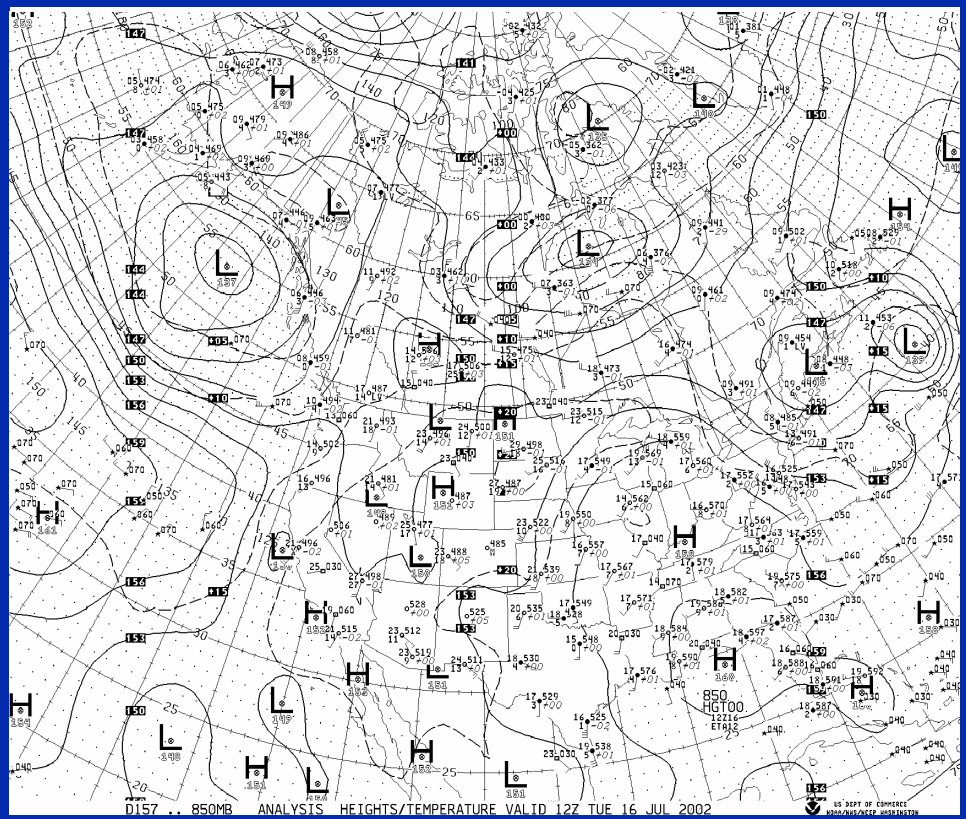
Current Conditions and Discussions

- First step is an orientation to current conditions
  - Where are we now?
  - What are the critical forecast issues?
- Key products
  - Upper-air charts
  - Surface analysis
  - Regional visibility observations
  - Satellite images
  - Air quality observations

Upper-Air Charts

There are many sources of upper-air charts, NCEP is the most comprehensive but other, more colorful, images are available (e.g., www.rap.ucar.edu).

This 850-mb chart shows a ridge over the central U.S. with a low pressure area over eastern Canada.

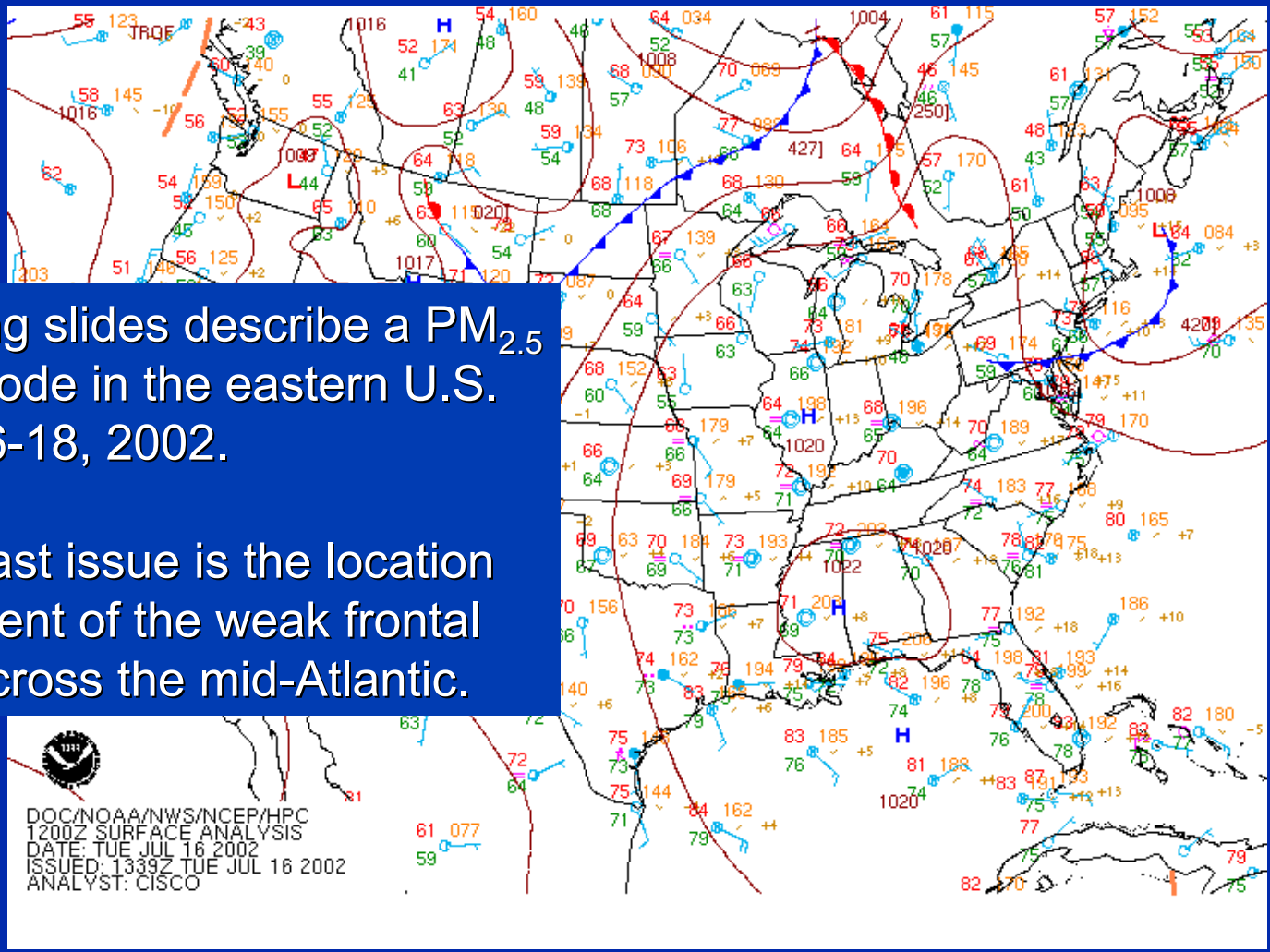


ftp://weather.noaa.gov/fax/QHUA04.TIF

Surface Analysis

The following slides describe a $PM_{2.5}$ and O_3 episode in the eastern U.S. from July 16-18, 2002.

A key forecast issue is the location and movement of the weak frontal boundary across the mid-Atlantic.



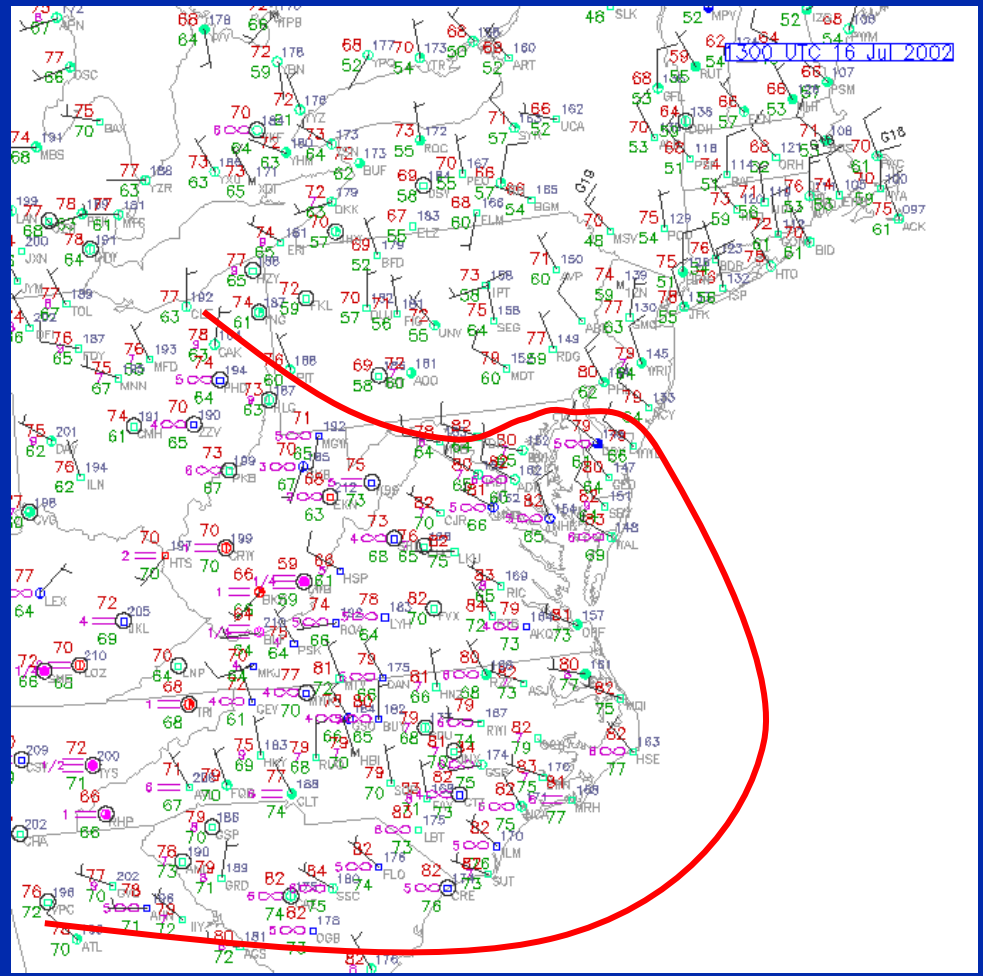
http://www.hpc.ncep.noaa.gov/html/sfc2.shtml

Regional Visibility Observations

Key weather symbols for air quality are haze (∞) and fog (=).

In this case, significant haze and fog reports are just southwest of the frontal boundary.

Where is this air mass headed?



http://www.rap.ucar.edu/weather/surface/

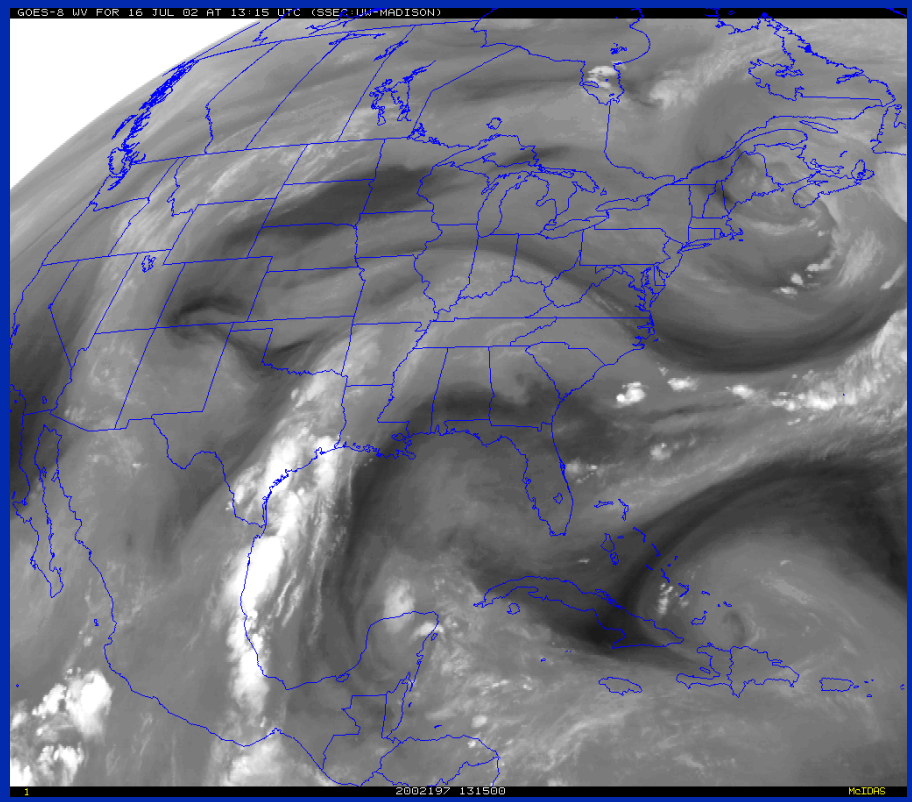
Clouds – Satellite Images (1 of 4)

The three main types of satellite images are water vapor, infrared, and visible.

Water vapor – good for locating areas of subsidence, small-scale circulations, and air mass differences. Best viewed as part of a loop.

On July 16, a plume of very moist air (whiter) is moving northeasterly from eastern TX.

Drier air (darker) and northwesterly flow is in New England and the mid-Atlantic.



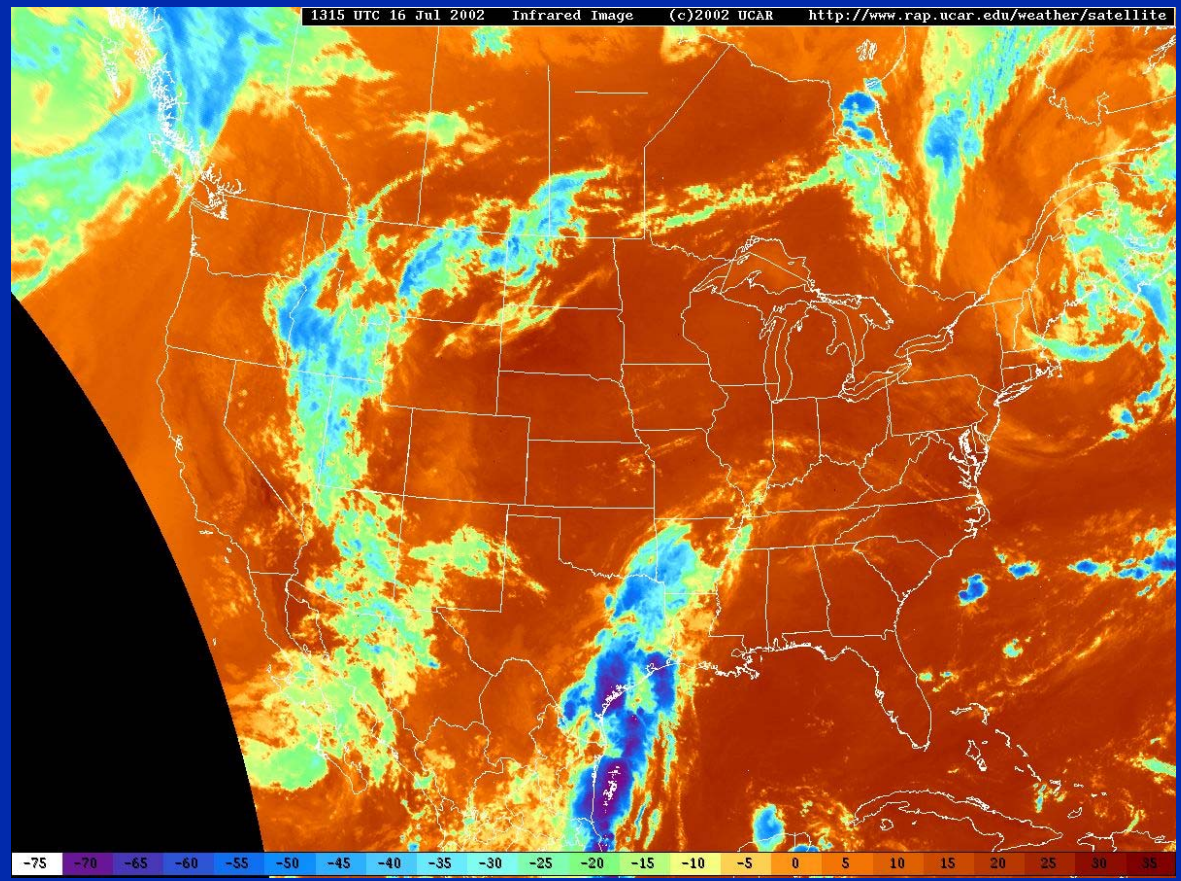
http://www.ssec.wisc.edu/data/g8/latest_g8wv.gif

Clouds – Satellite Images (2 of 4)

Infrared – available day or night, based on temperature. Poor for low clouds and fog; good for mid- and high-level clouds.

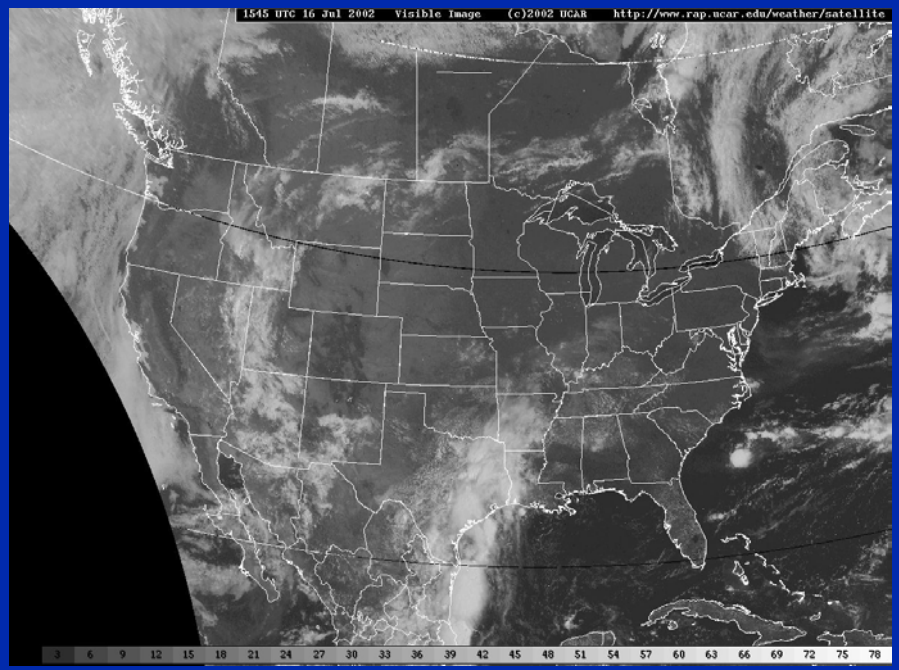
Clouds associated with the plume of moist air seen in the Mississippi Valley.

This IR image is enhanced to show temperature/height of clouds.

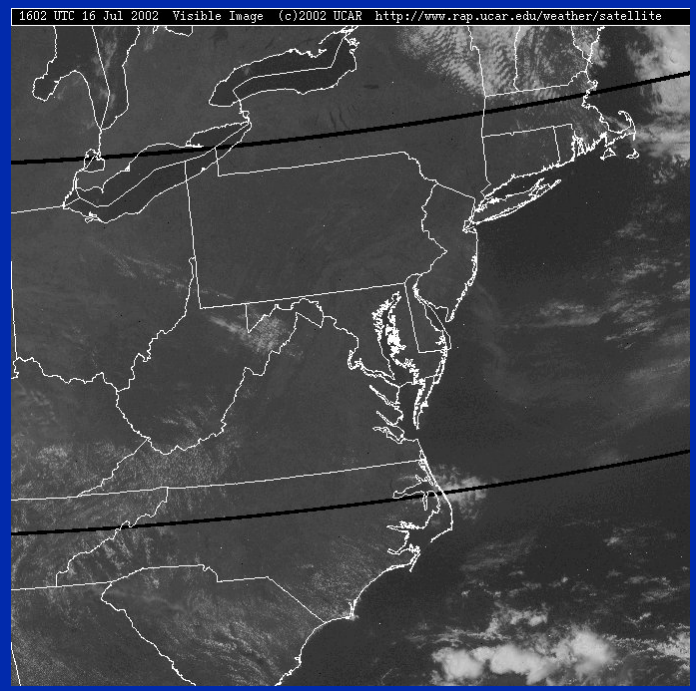


Clouds – Satellite Images (3 of 4)

Visible – available during the day. Good for low clouds, haze, and fog. Morning images are good for identifying regions of haze.

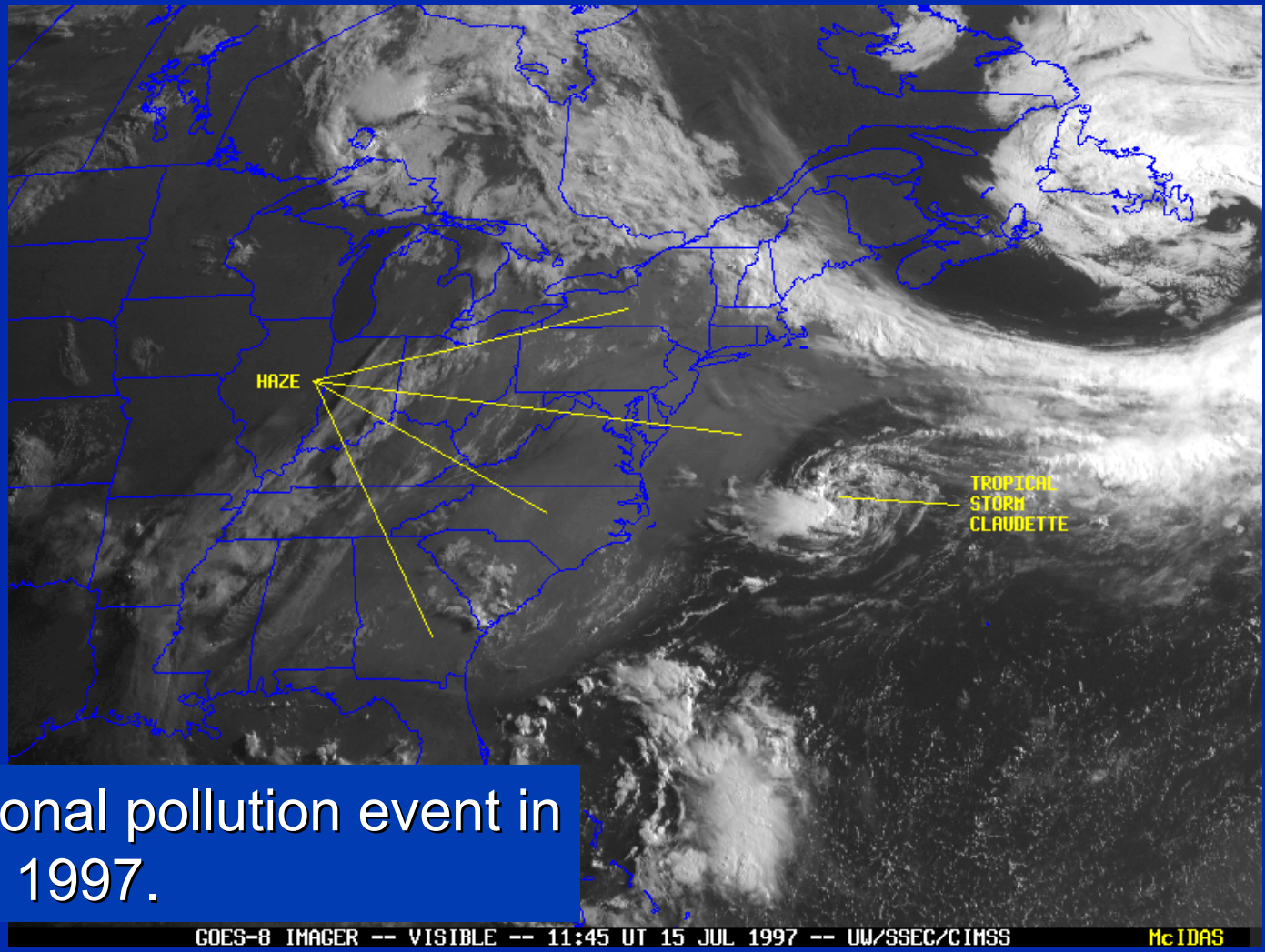


GOES US image:
http://www.rap.ucar.edu/weather/satellite/latest_US_vis.jpg



GOES high resolution:
http://www.rap.ucar.edu/weather/satellite/

Haze – Satellite Images (4 of 4)

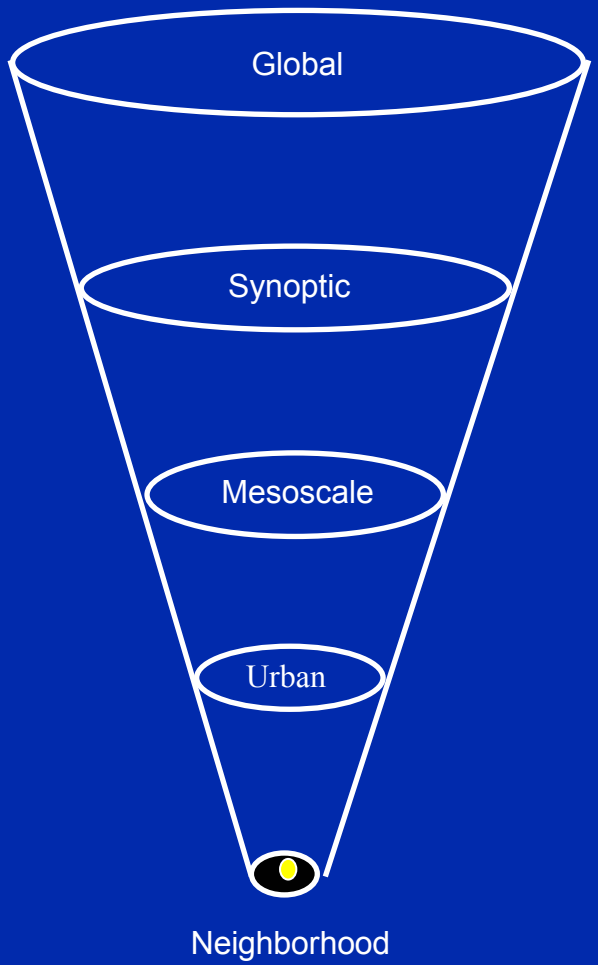


Regional pollution event in July 1997.

Analysis of Forecast Models

- What does NCEP think about the models?
  (model diagnostics)
- What do the Local NWS forecasters think?
  (local discussions)
- What do the "model(s) of choice" say about the key air quality forecast parameters:
  mixing depth, wind speed, transport, thunderstorms, cloud cover, etc.

Overview of Forecast Models



GFS: Global Forecast System (previously MRF/AVN)
0-384 hours, runs 4 x day (00, 06, 12, 18 UTC)
Grid resolution ~ 55 km to 84 h, ~75 km to 180 h
Provides long-range guidance

Eta: NCEP short-range forecast model
Now running at 12-km resolution with 60 layers
Runs 4 x day (00, 06, 12, 18 UTC)
00 and 12 UTC to 0-84 h, 06 and 18 UTC to 0-48 h

MM5: Regional/mesoscale model, run at many locations
Runs typically 1 to 4 x day
Resolution varies from 4-12 km
0-48 h

MOS: Model Output Statistics
Model output (T, moisture, wind) related to sensible weather (clouds, max/min temperature, rain probability)

http://www.nco.ncep.noaa.gov/pmb/products/

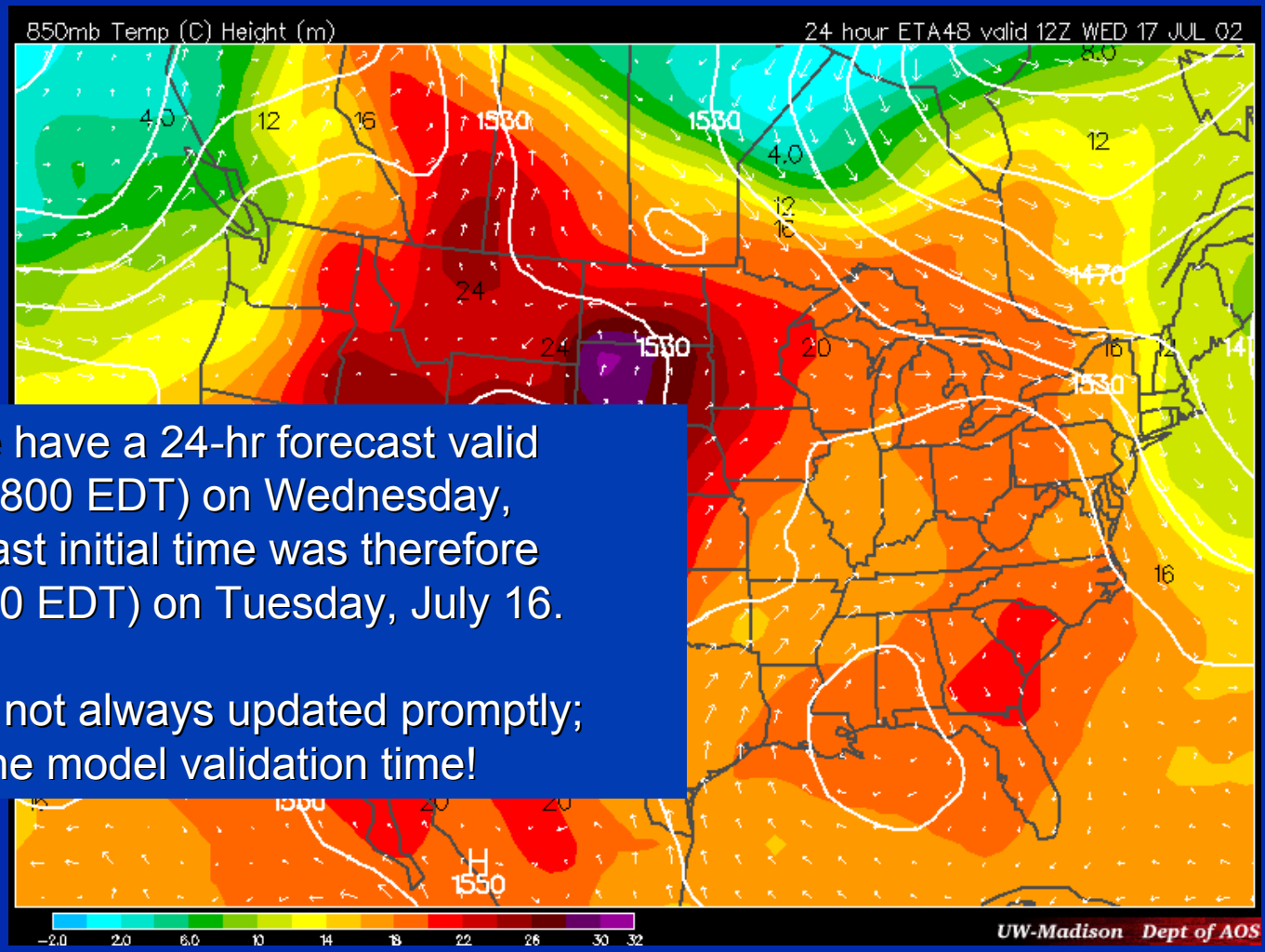
Models – Time Standards (1 of 2)

- Time in weather products
  - UTC/Zulu/GMT

	PST	MST	CST	EST
Hours from UTC	-8	-7	-6	-5

- Example: 00Z Feb 2 = 1800 CST Feb 1
  (For summer, it would be 1900 CDT)
- Forecast time periods
  - Forecast validation time
  - Based on model initialization time (00 or 12 UTC) +
    Forecast periods 12, 24, 36, 48, 72, 96 hrs., etc.
- Example: 24-hr forecast from a 12 UTC model run is valid at 12 UTC the next day

Models – Time Standards (2 of 2)



In this case, we have a 24-hr forecast valid at 1200 UTC (0800 EDT) on Wednesday, July 17. Forecast initial time was therefore 1200 UTC (0800 EDT) on Tuesday, July 16.

Model data are not always updated promptly; always check the model validation time!

Analysis of Forecast Models

This is a course in itself.

Issues to consider:

- Understand the differences between models, especially with respect to phenomena that influence air quality.
- Looping the forecast fields will show if any important differences exist.
- Read discussions to see what NCEP/NWS forecasters think is helpful.
- Keep previous model runs to check run-to-run consistency. A consistent forecast is often a reliable forecast.

Models – Local Discussion

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE BALTIMORE/WASHINGTON
330 AM EDT WED JUL 17 2002

TDY THRU THU...

HIGH PRES SFC AND ALOFT WL DOMINATE MID ATLC RGN TDY. COMBINATION OF H85 TEMPS ARND +20 DEG C AND WNW DOWNSLOPE FLOW WL PUSH TEMPS

INTO M90S THIS AFTN. PROJECTED DWPTS WL BE IN M/U 60S AND RESULTANT HEAT INDICES WL BE ARND 100 DEG. HV REISSUED THE HEAT ADVIS AND EXPANDED IT TO INCL COUNTIES IN NW PTN OF ERN WV PANHANDLE WHICH TEND TO BE AS WARM AS AREAS TO THE E UNDER THIS TYPE OF PTTN.

S/W OVR SRN CANADA WL PUSH CDFNT FM NRN TIER OF U.S. INTO PA BY THU AFTN. STEERING FLOW BETWEEN HIGH PRES OVR GULF STATES AND APPCHG

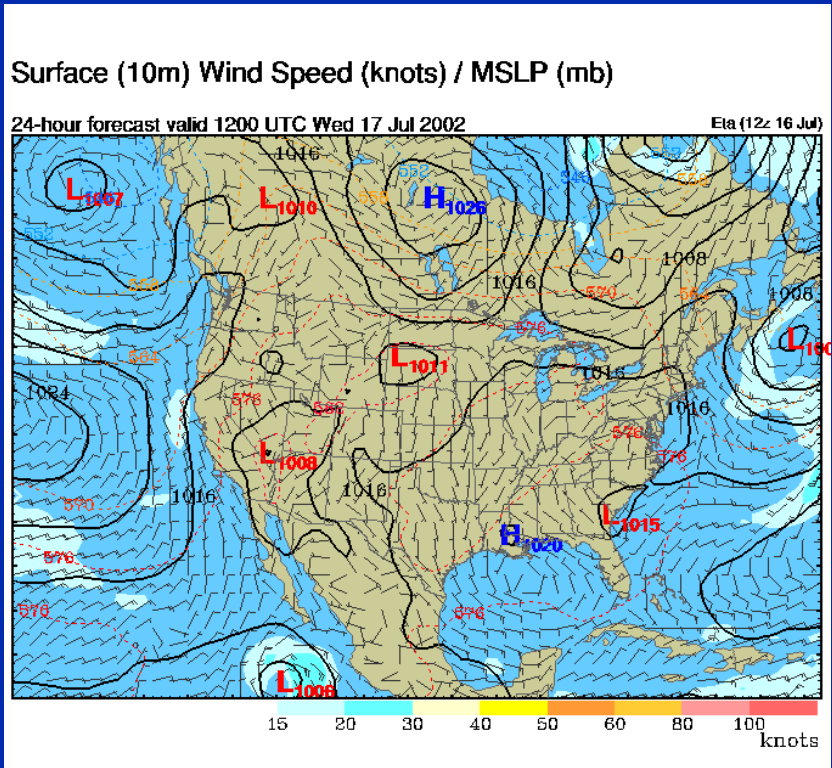
FRONTAL SYS WL BRING MOISTURE EWD FM SRN PLAINS. AVN WAS A BIT TOO AGGRESSIVE IN MOVG SRN PLAINS MOISTURE EWD THIS AM SO LEANED TWD SLOER MVMNT OF ETA/NGM.

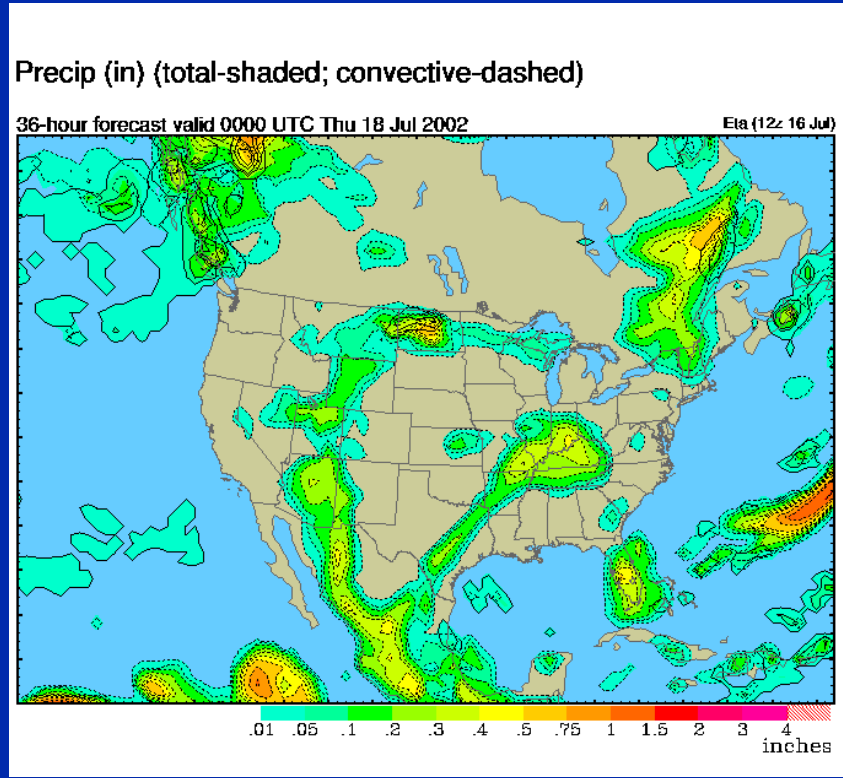
CLDS WL INCR OVR RGN TNGT. ON THU WL CONT CHC TSRA/S BUT CONFINE TIMING TO AFTN AS FRONT WL BCM MORE PARALLEL TO STEERING FLOW W/TIME AND WL ONLY SLOLY APPCH FA. GUIDANCE TEMPS IN 70S SEEM FINE FOR TNGT. POTENTIAL EXISTS FOR HEAT ADVIS CRITERIA TO BE MET AGN ON THU.

HOWEVER...MAY HV ENUF CLDS ARND TO KEEP HEAT INDICES BLO THE CRITERIA. WL WAIT FOR FUTURE MDL RUNS BFR EXTENDING HEAT ADVIS ANOTHER DAY.

ARTHUR

Models – Surface Forecasts





http://www.rap.ucar.edu/weather/surface/us_mslp.gif

http://www.rap.ucar.edu/weather/model/ruc12hr_sfc_prcp.gif

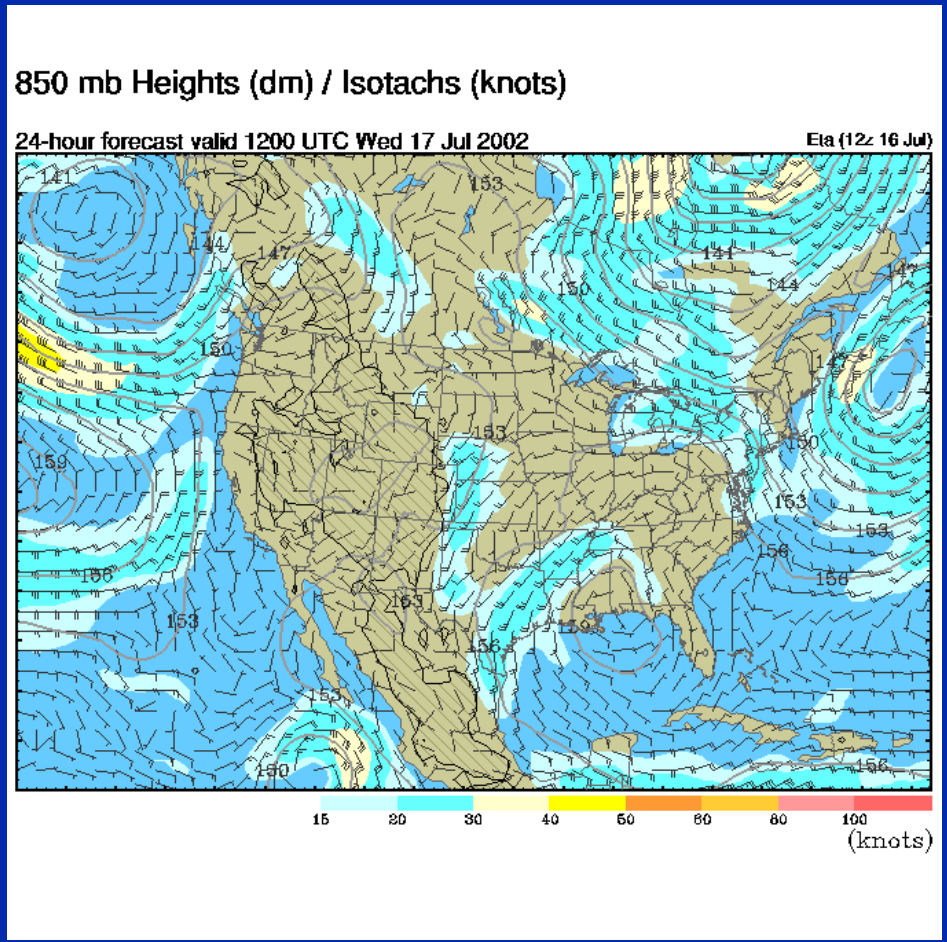
While surface pressure fields show a broad, featureless area of high pressure over the eastern U.S., rain is forecast by evening over the Ohio River Valley.

Models – Upper-Air Forecasts

For most air quality issues, knowledge of the 850- and 500-mb charts are most important.

Here, strong winds at 850 mb are forecast for early on July 17 across the mid-Atlantic with maritime Gulf air pushing into the Ohio River Valley.

Winds suggest haze stays west of the I-95 Corridor on July 17.



http://www.rap.ucar.edu/weather/model/ruc12hr_850_wnd.gif

Critical Forecast Parameters

- At this point, we are oriented to current weather, have looked briefly at the models, and have read discussions to determine our model of choice and key forecast questions.
- Now, what do the models imply about air quality?
  - Mixing Depth
  - Transport
  - Wind speed and direction
  - Rain and cloud cover

Mixing Depth

Three basic types of images can give mixing depth

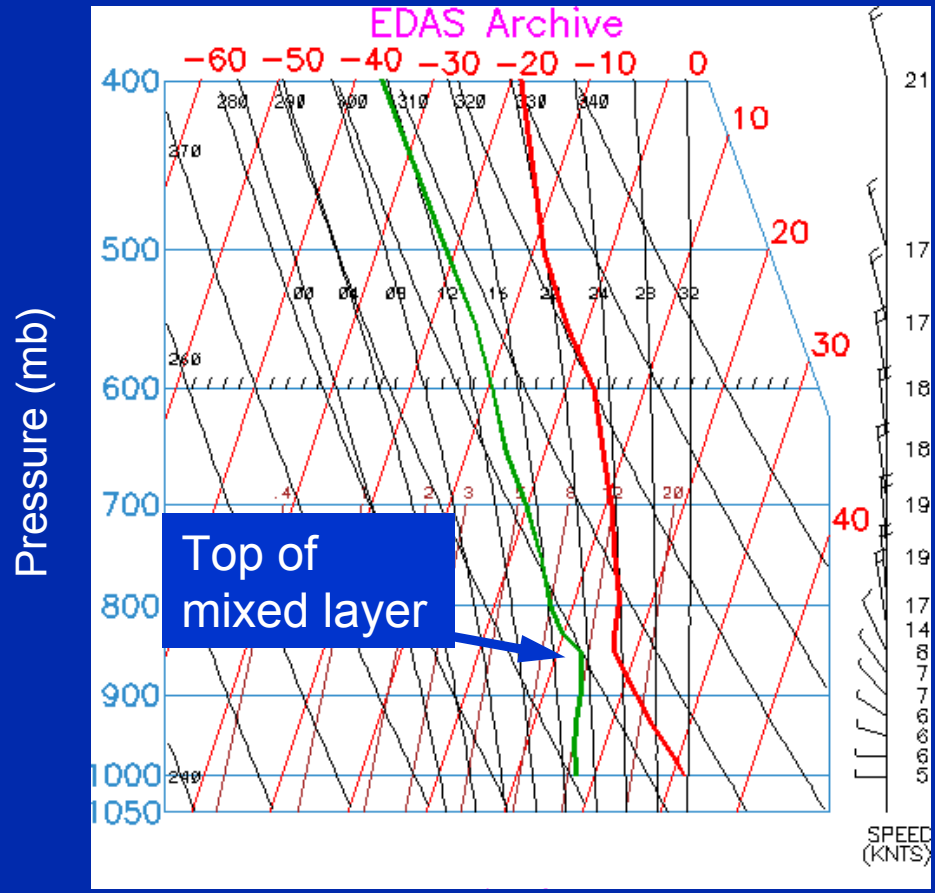
- Skew T diagrams
- Vertical cross-sections
- Explicit solution for boundary layer depth

For average mixing depths for your location see Holzworth (1972).

Mixing Depth (Skew T)

Mixing depth typically peaks in the afternoon. Use 1800 or 2100 UTC forecast soundings.

Mixed layer has ~ constant water vapor with temperature decreasing adiabatically.



http://www.arl.noaa.gov/ready/cmet.html

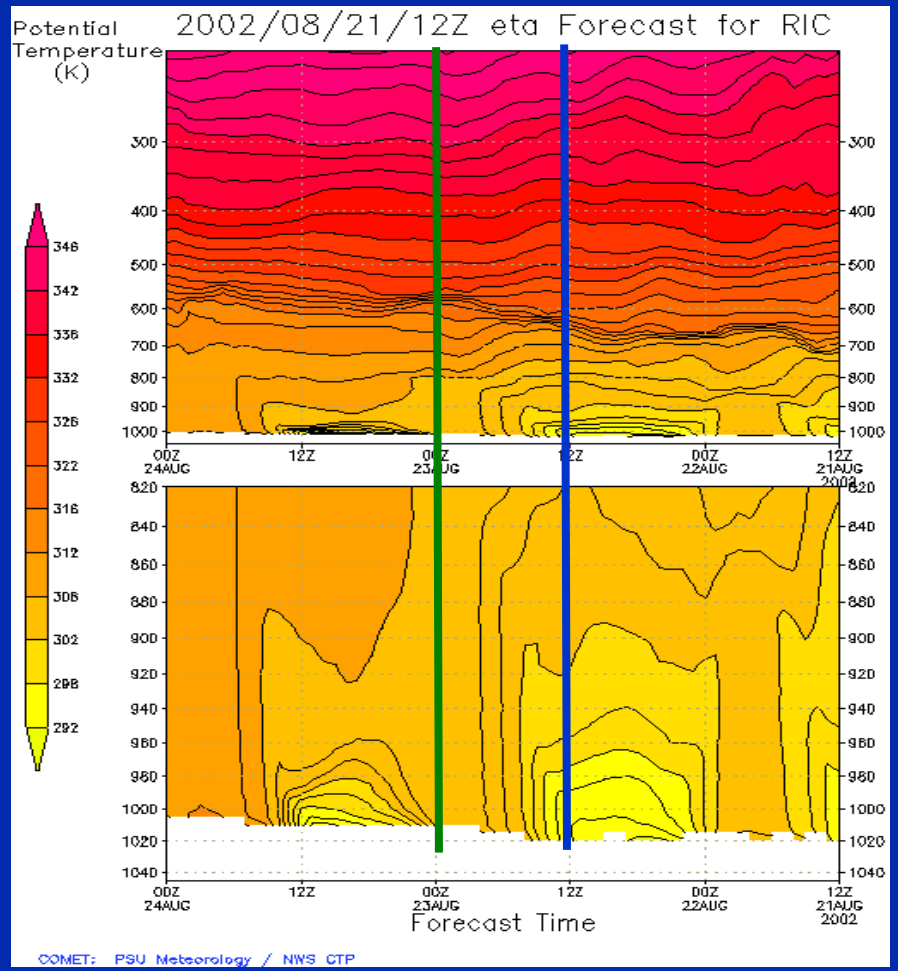
Understanding skew T diagrams
http://weather.unisys.com/upper_air/skew/details.html

Mixing Depth (Cross-sections) (1 of 2)

Turbulence results in a well-mixed layer characterized by constant potential temperature (θ).

Cross-sections of θ show the evolution and depth of the mixed layer.

At 1200 UTC (blue line), θ increases with height (stable, shallow mixed layer); by 0000 UTC (green line), θ is constant through 800 mb. Mixing depth is ~ depth of constant θ layer.

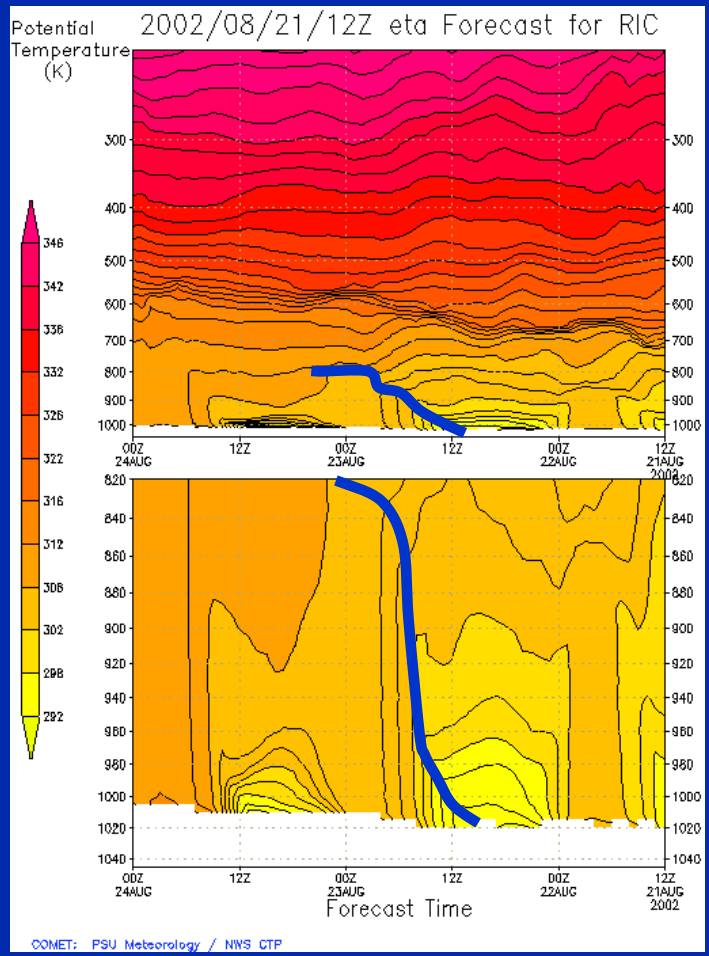


http://www.ems.psu.edu/wx/etats.html

Mixing Depth (Cross-sections) (2 of 2)

The mixed layer on August 22 is forecast to reach a maximum of ~ 800 mb or 2 km late in the day.

But, slow evolution of the mixed layer allows O_3 to build up to Unhealthy for Sensitive Groups (USG).

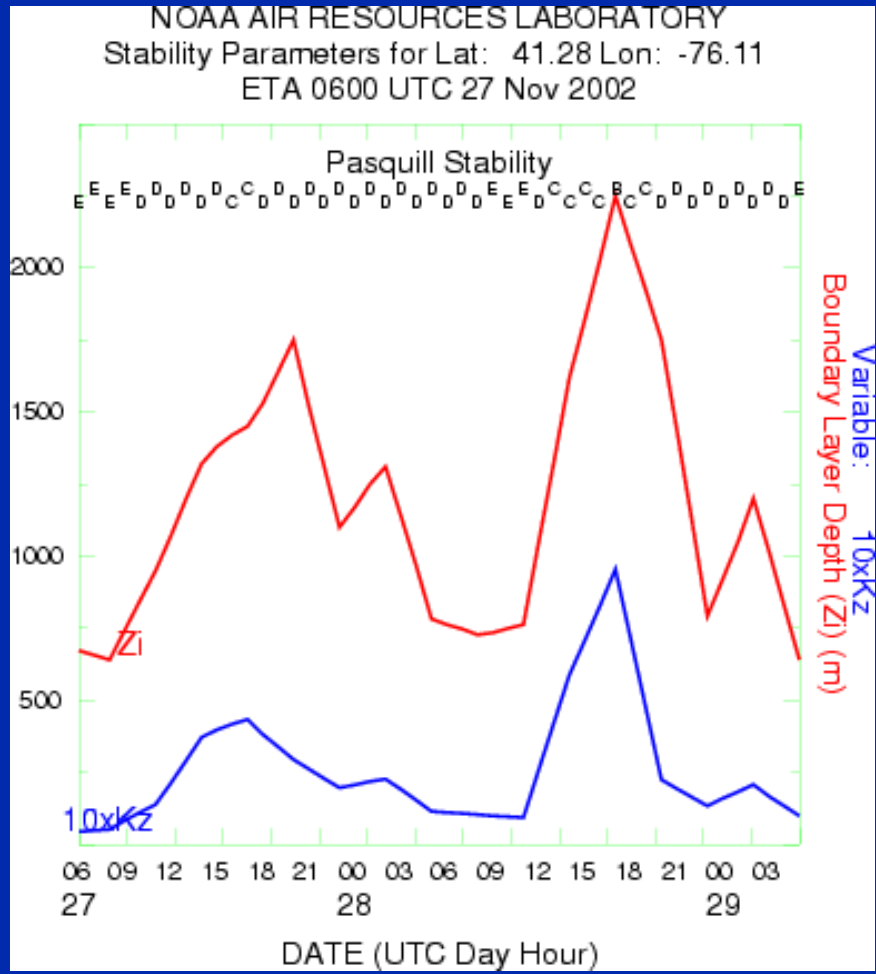


Mixing Depth (Model Output)

Mixing depth can also be derived from other model output variables.

MM5 models typically provide this information, though an Eta example is shown here.

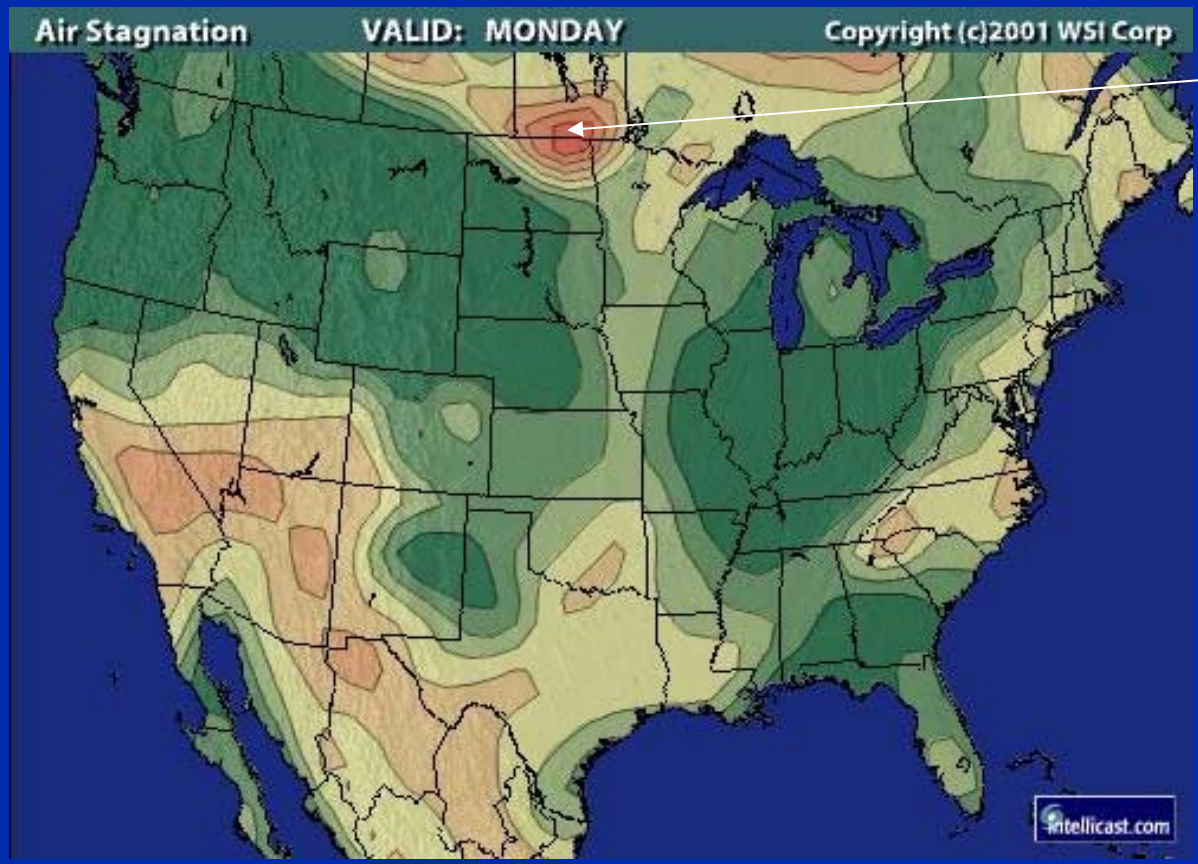
Note: This is a derived parameter, use carefully.



http://www.arl.noaa.gov/ready/cmet.html

Mixing – Air Stagnation Maps

- Air stagnation map (wind speed x mixing height)
- Often referred to as the ventilation index



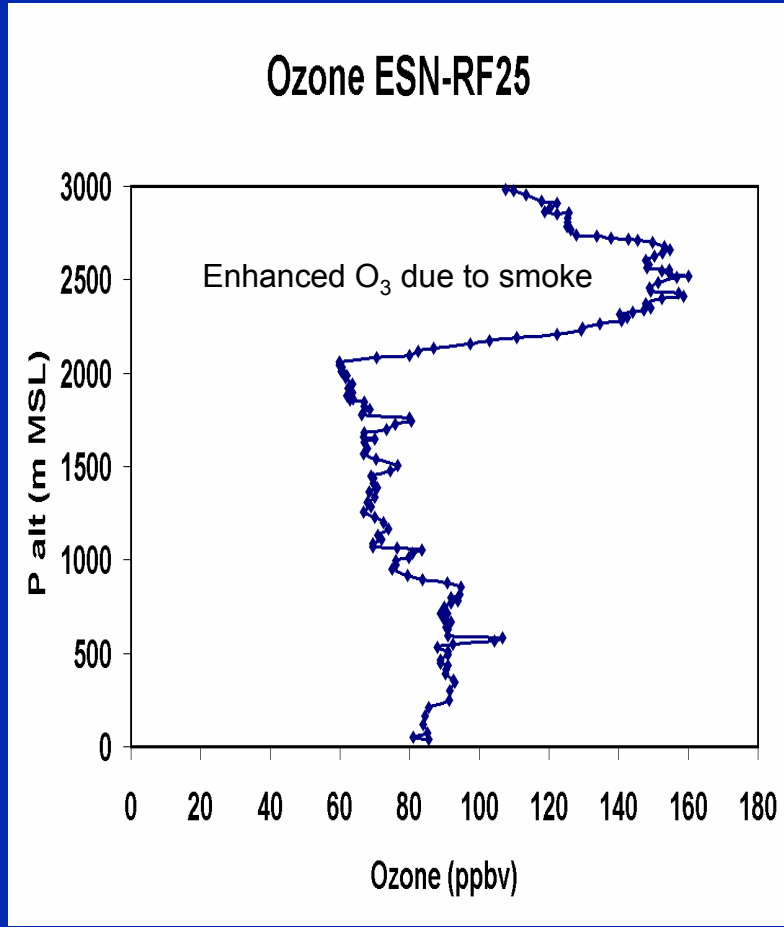
Very little ventilation

http://www.intellicast.com/Health/ (click on “Respiratory”)

Transport (1 of 2)

Transport of air pollutants can occur over very long time and distance scales.

This O_3 profile from the July 8, 2002, Quebec wildfire episode is from the Eastern Shore of Maryland.



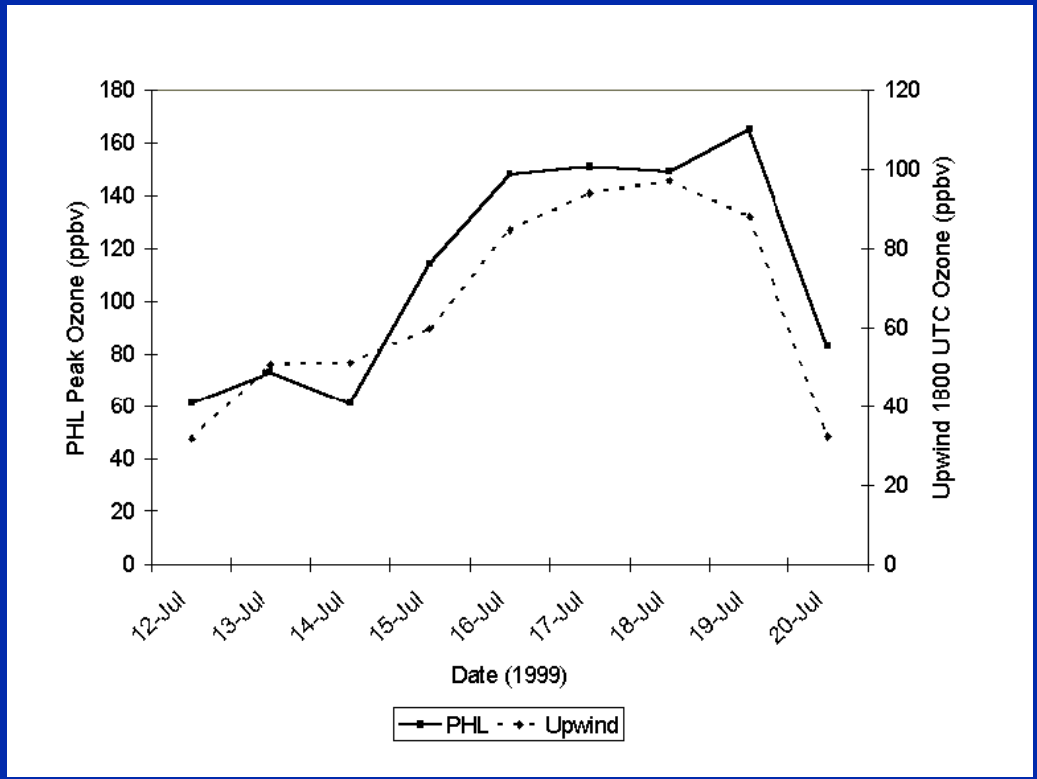
Courtesy of Bruce Doddridge, Lackson Marufu, and Brett Taubman, Univ. of Maryland – Meteorology.

Transport (2 of 2)

Upwind concentrations on the current day can be a strong indicator of tomorrow's air quality.

In this case, noon O_3 upwind of Philadelphia (PHL) (dashed line) is compared to next-day peak O_3 in PHL.

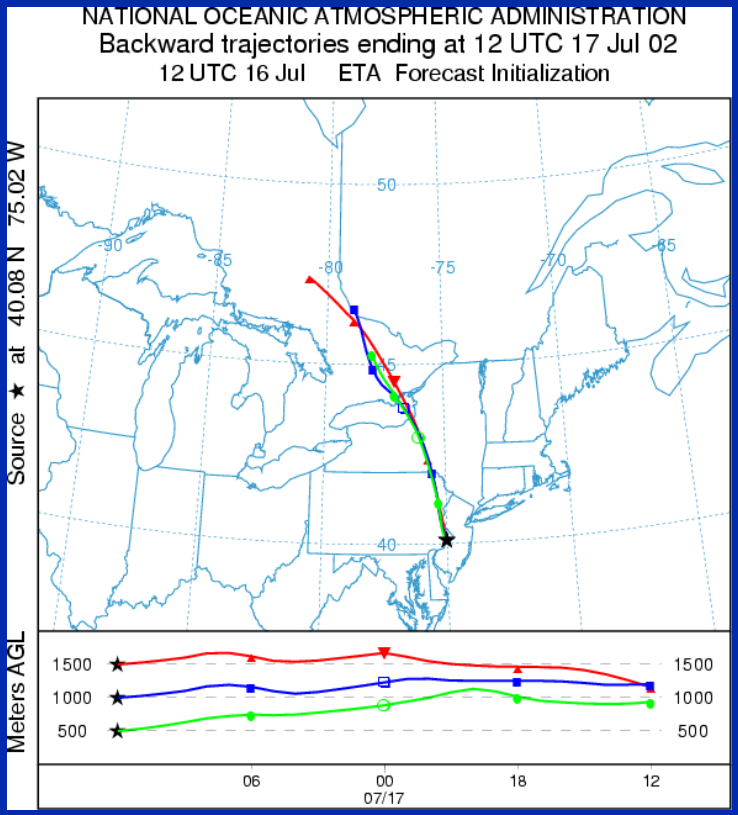
Upwind area is determined by backward trajectories.

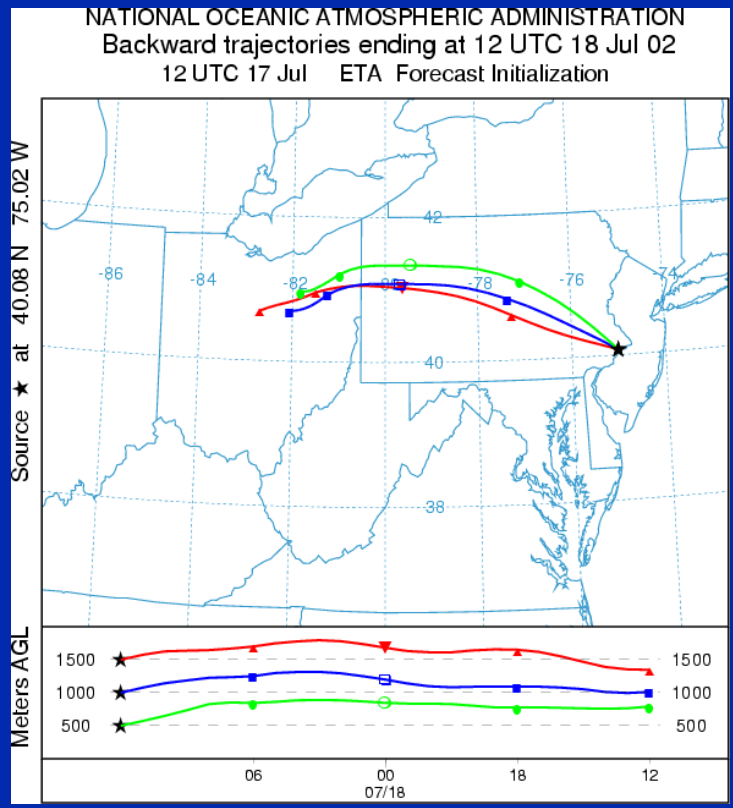


Transport – Use of Back Trajectories

- Back trajectories show where the air mass is coming from and, coupled with AIRNow data, can give information about tomorrow's air quality.
- The HYSPLIT model is the back trajectory model of choice (http://www.arl.noaa.gov/ready/hysplit4.html).
- Be careful how you use it:
  - Accuracy decreases close to the surface – use 300 to 500 m or higher (depends on location and season).
  - Accuracy is ~ 20-30% of trajectory length.

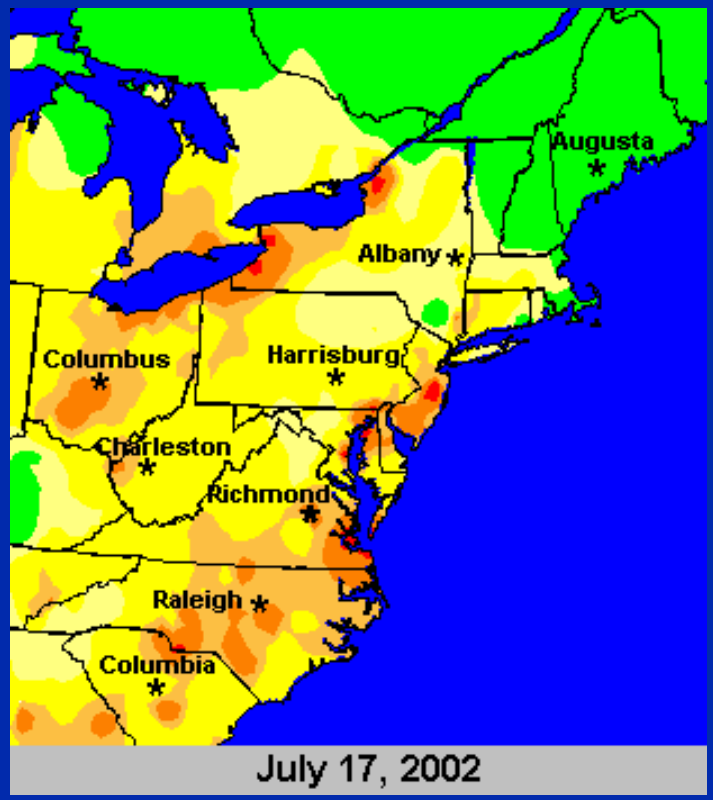
Back Trajectories – Example (1 of 4)

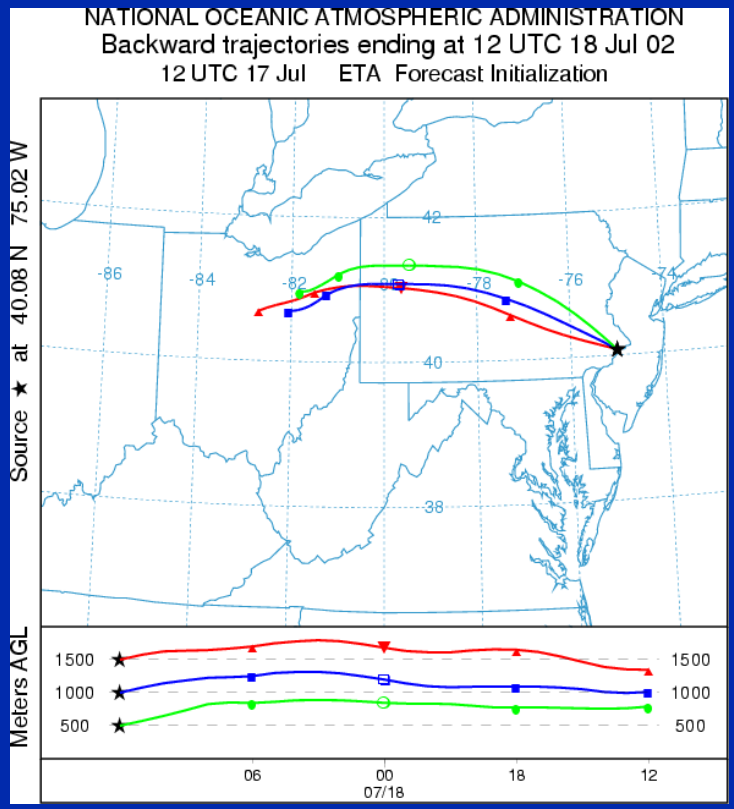




Back trajectories show air parcel paths from north-northwest to west from July 17 to July 18.

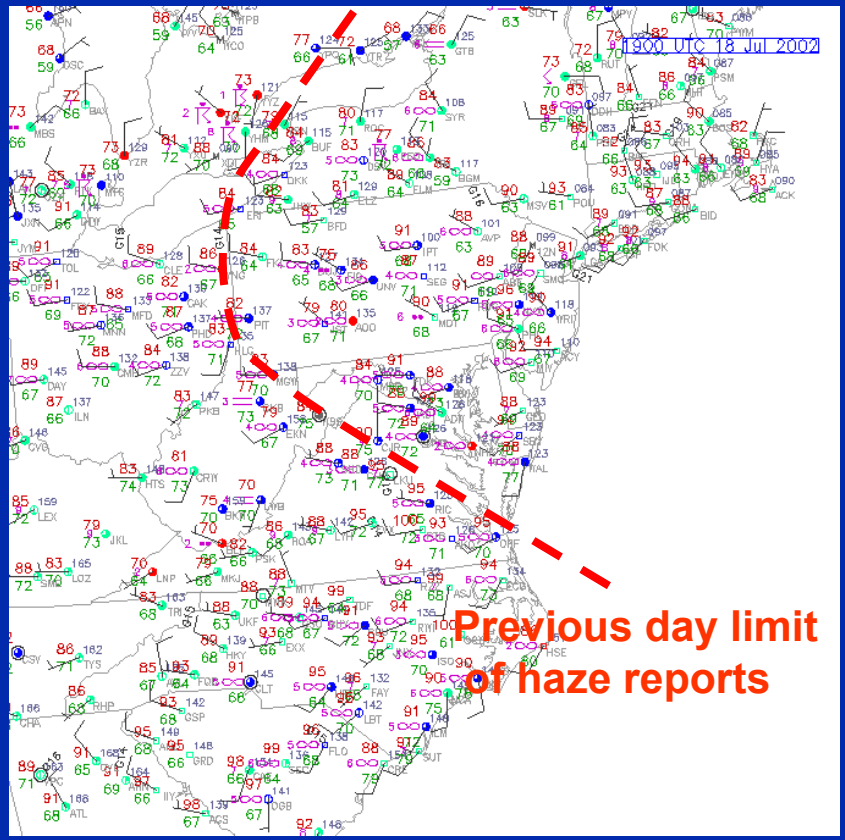
Back Trajectories – Example (2 of 4)

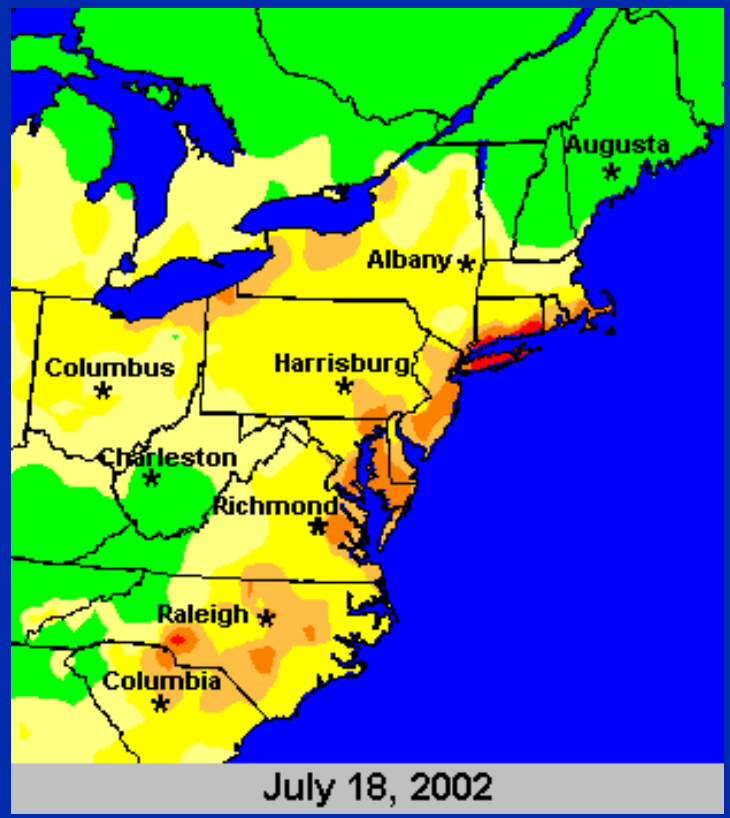




Ozone is enhanced south and west of the retreating front. Upwind (west) of the mid-Atlantic ozone, haze, and PM increase.

Back Trajectories – Example (3 of 4)



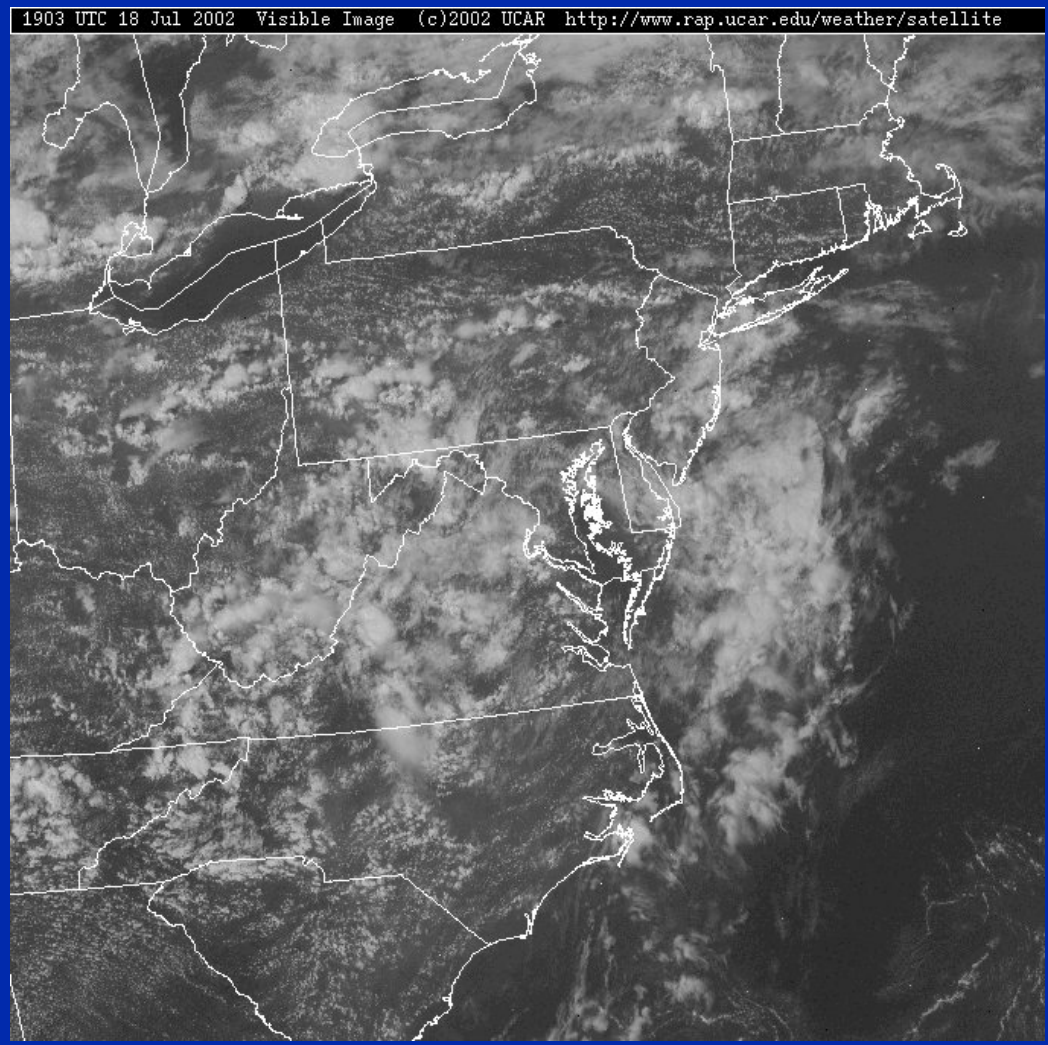


Haze spreads rapidly east, $PM_{2.5}$ increases rapidly at PHL to the USG range by evening but O_3 increases only slightly.

Back Trajectories – Example (4 of 4)

PM and haze responded directly to westerly transport, while O_3 concentrations were limited by an influx of clouds.

In Connecticut, where only shallow cumulus clouds were reported, O_3 reached Unhealthy.



Wind Speed and Direction

Critical Factors:

- Stagnation
- Recirculation
- Sustained flow from “dirty” direction

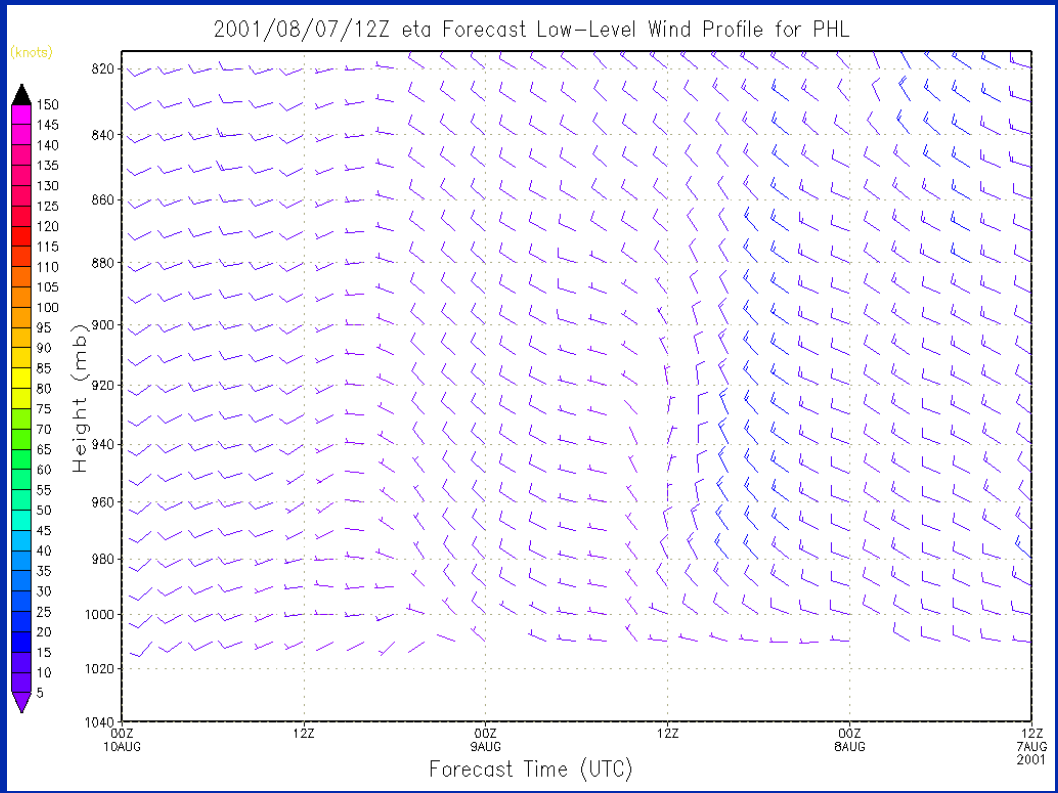
Meteograms and cross-sections are most effective in showing these effects but:

- Is the resolution (i.e., size of grid cells) of the model sufficient to resolve the phenomena of interest?
- Only the finer resolution models (e.g., MM5) can resolve some key effects such as bay breezes that can lead to local-scale recirculation.

Winds – Cross-section (1 of 2)

This cross-section for August 7-9, 2001, shows light westerly winds on August 8 in Philadelphia (PHL).

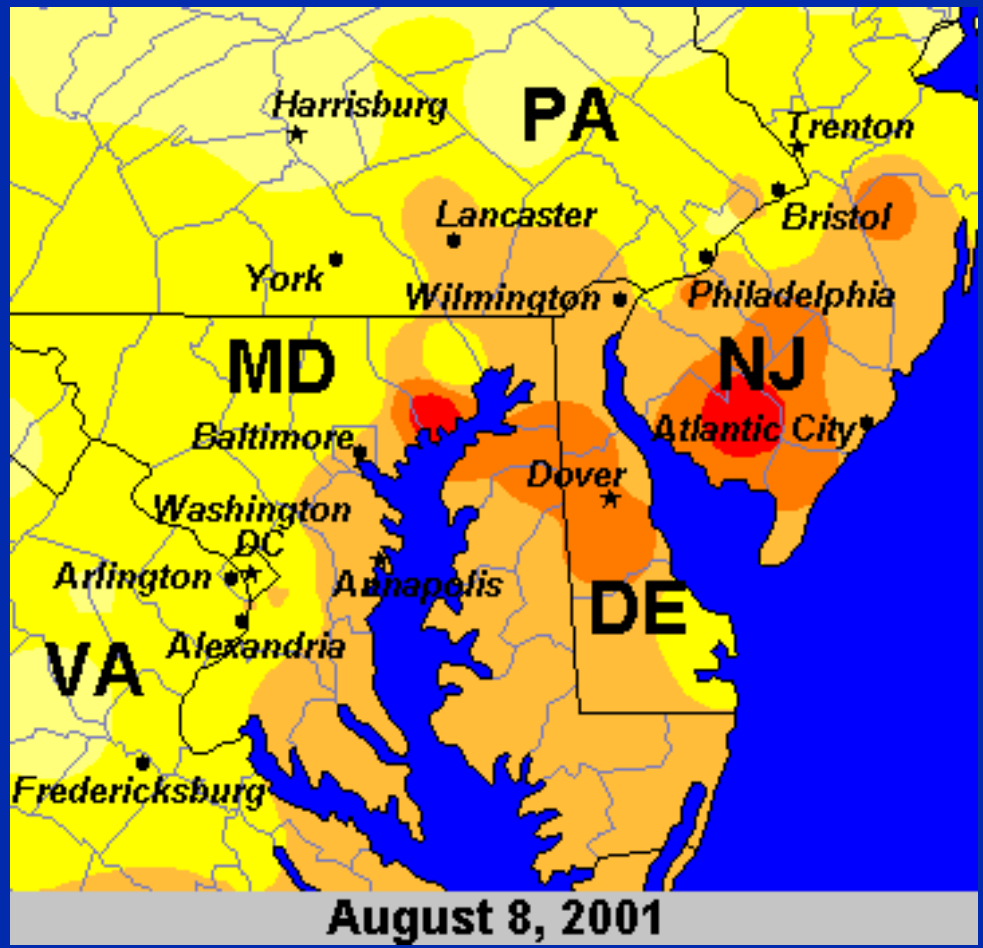
Similar forecast, not shown here, for Baltimore (BWI).



http://www.ems.psu.edu/wx/etats.html - Eta Time-Height (T-Z) Cross Sections

Winds – Cross-section (2 of 2)

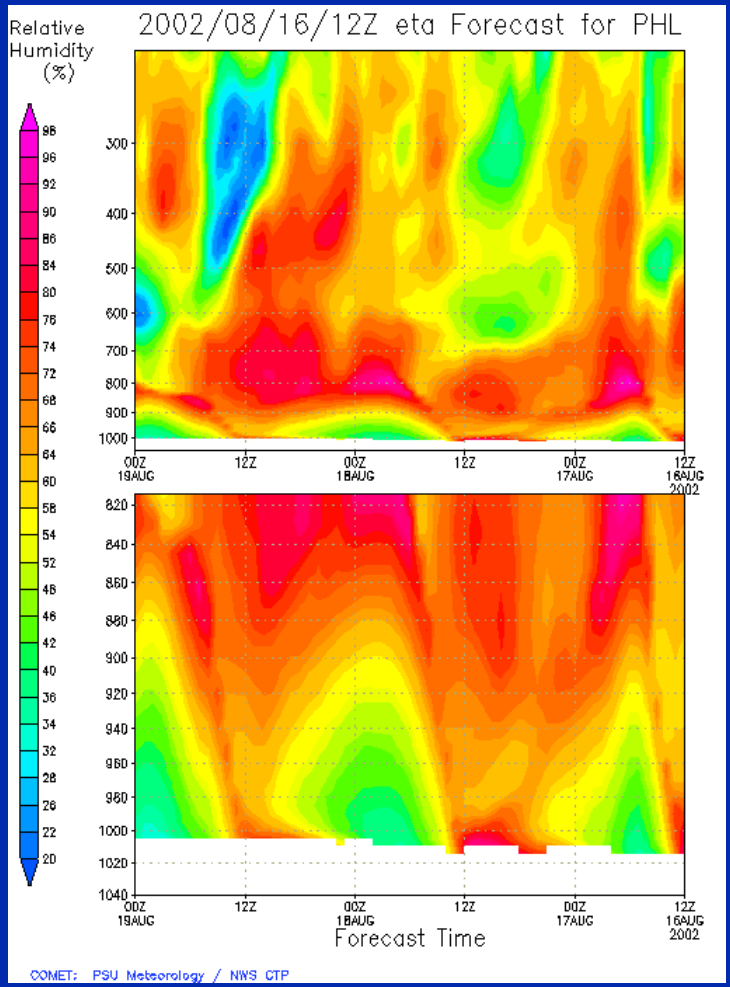
The Philadelphia O_3 plume follows the expected wind, but bay breeze recirculation near Baltimore was not resolved.



Relative Humidity – Cross Section

Cloud cover is not directly determined by the forecast models but can be inferred from relative humidity fields.

Shallow clouds are forecasted for PHL on August 16-17 with increased clouds later on August 17.



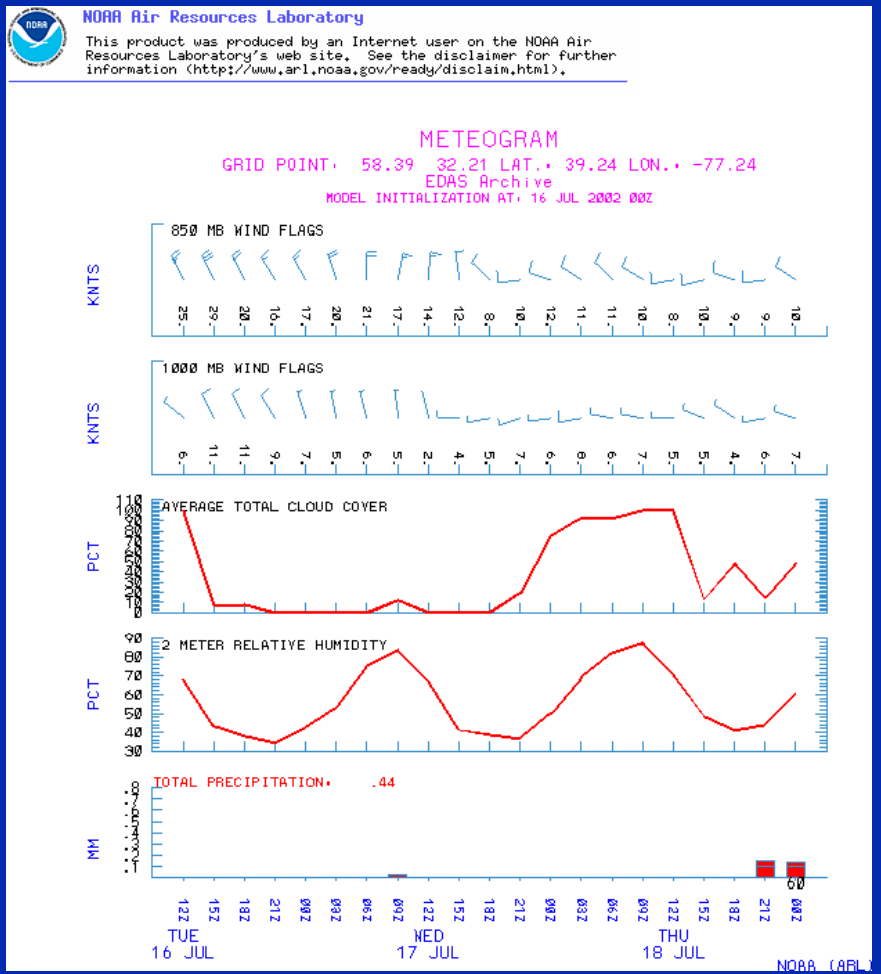
http://www.ems.psu.edu/wx/etats.html

Winds, Clouds, Relative Humidity, and Precipitation – Meteograms

Meteogram for Washington-Dulles during July 16-18

Note:

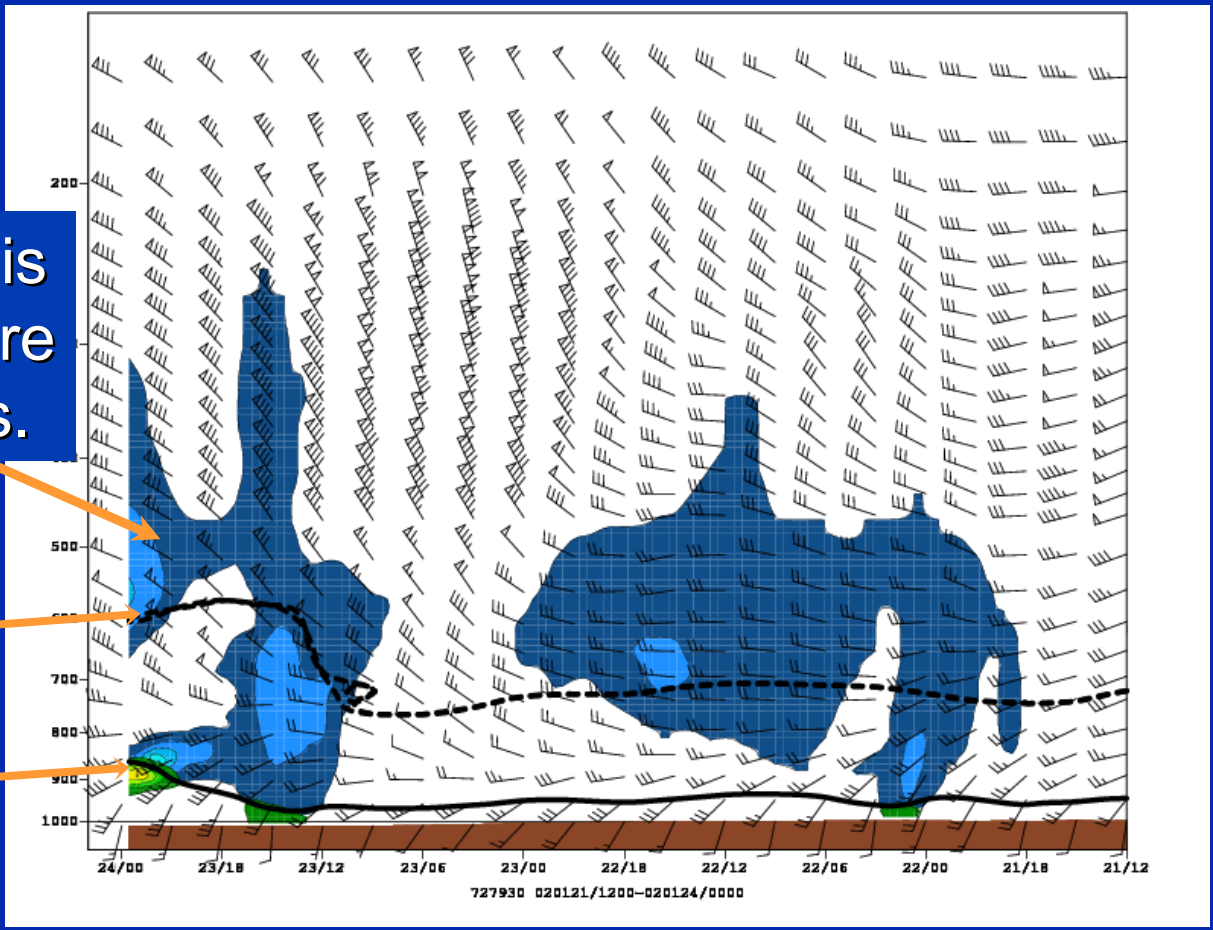
- Wind shift to the west begins in the late morning of July 17.
- Cloud cover is forecast too early on July 18.



http://www.arl.noaa.gov/ready/cmet.html

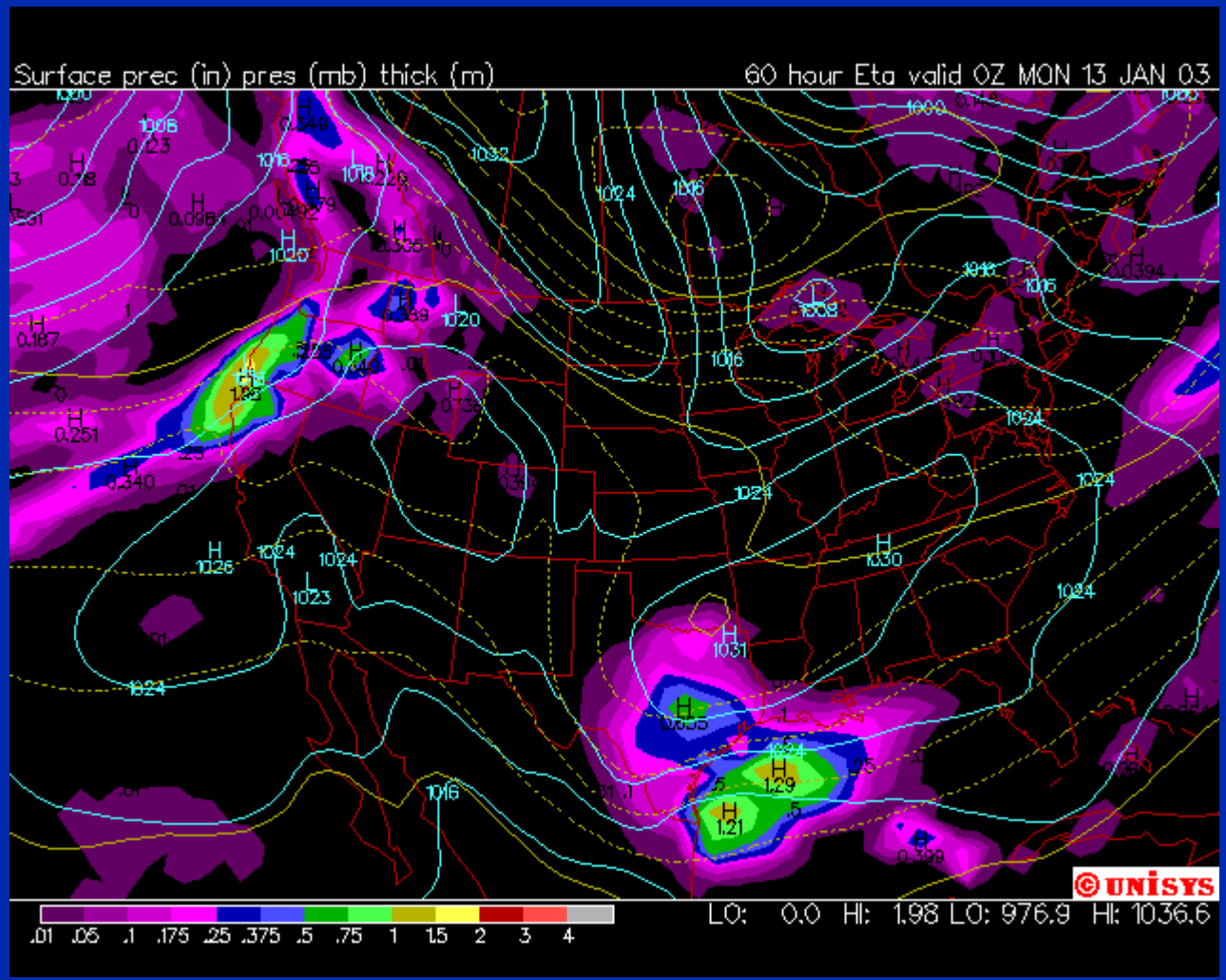
Clouds and Wind – Cross Section

H_20 mixing ratio is plotted, clouds are inferred from this.



http://www.emc.ncep.noaa.gov/mmb/meteograms/

Precipitation and Surface Pressure



http://weather.unisys.com

Air Quality Forecasts – Input to Statistical Models

Many locations rely on statistical forecast models to provide “first guess” guidance for forecasters.

Statistical models require meteorological inputs

- Temperature
- Wind speed and direction
- Moisture, etc.

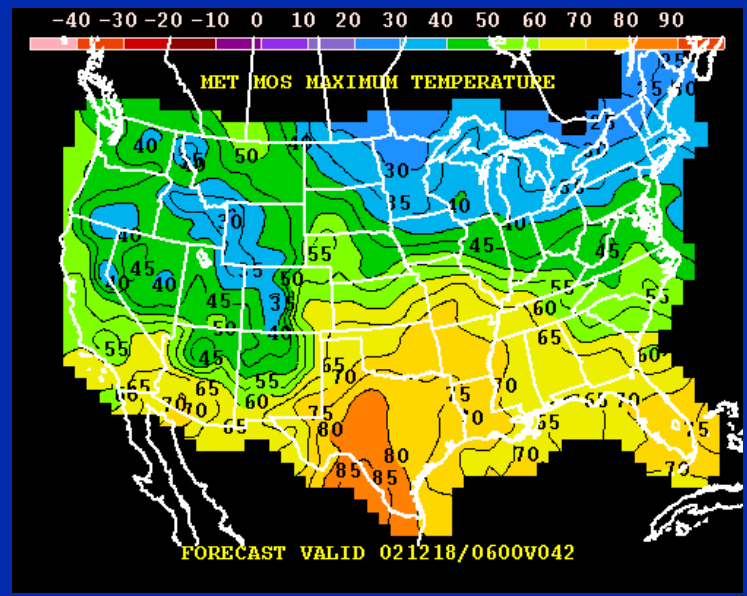
A variety of sources for this data exist

- Forecast soundings (text)
- Model Output Statistics (MOS)
- Local NWS forecasts

Air Quality Forecasts – Model Output Statistics (MOS)

MOS is

- Based on historical comparisons of meteorological model output and observations
- A conversion of model output to what historically occurred when the model had similar predictions
- Helpful for many key forecast parameters
  - Temperature
  - Wind speed and direction
  - Frontal passage timing
  - Cloud cover
- Available in both tabular (text) and graphic format

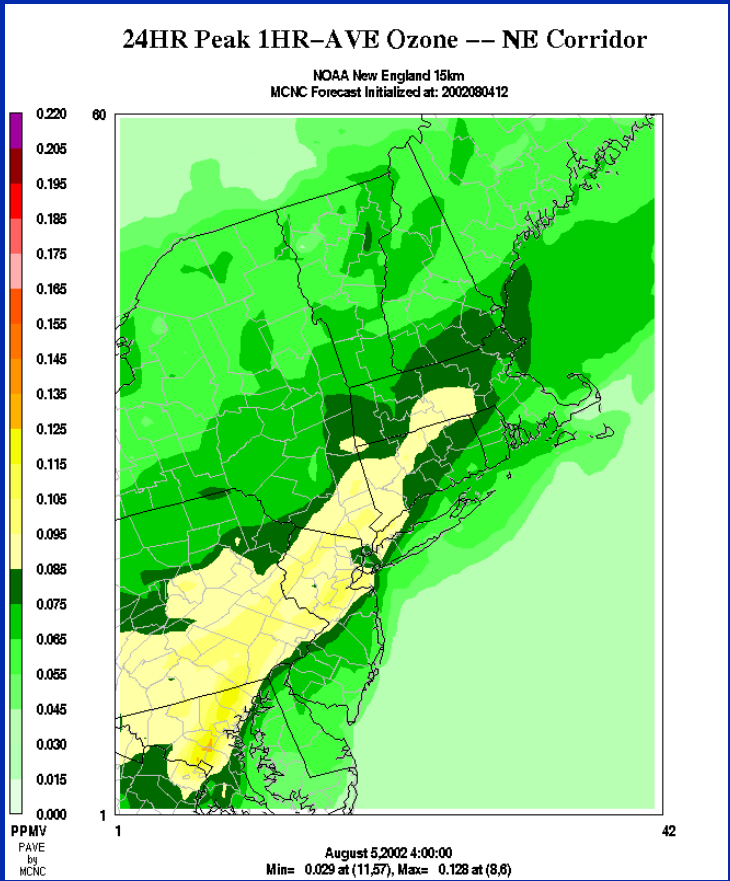


http://isl715.nws.noaa.gov/mos/products/MET/
http://www.nws.noaa.gov/mdl/synop/products.htm

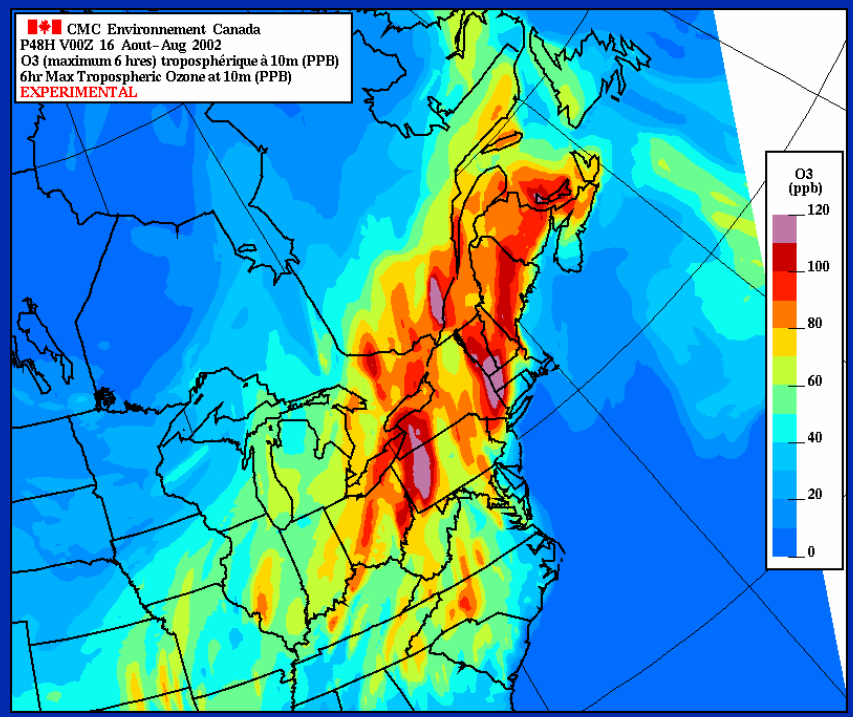
Air Quality Forecasts – Air Quality Data

- Current local air quality and upwind air quality are often critical forecast parameters used by statistical models.
- AIRNow is the best source for near real-time observations (http://www.epa.gov/airnow/).
- Forecast models directly predicting air quality are now routinely available and will be supported in a more comprehensive manner by NOAA in the coming years (http://www-frd.fsl.noaa.gov/aq/).

Air Quality Forecasts – Air Quality Forecast Models



http://www.emc.mcnc.org/projects/SECMEP/index.html



http://www.smc-msc.ec.gc.ca/aq_smog/chronos_e.cfm

Air Quality Forecasts – Relationship with NWS

For the most effective use of regional-scale forecast models, and to benefit from advances in the field, initiate a good working relationship with the local NWS forecasters and local university meteorology departments.

This relationship can benefit both parties as the following slide demonstrates.

Air Quality Forecasts – Benefits of Coordination with NWS

486
FXUS66 KSEW 242217
AFDSEW

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE SEATTLE WA
220 PM PST SUN NOV 24 2002

.SYNOPSIS...A RIDGE OF HIGH PRESSURE OVER THE PACIFIC NORTHWEST WILL STRENGTHEN AND PERSIST THROUGH THIS WEEK...KEEPING THE WEATHER DRY WITH AREAS OF NIGHT AND MORNING FOG.

.DISCUSSION...MODELS REMAIN QUITE CONSISTENT IN BUILDING AND MAINTAINING THE UPPER LEVEL RIDGE NOW CENTERED OVER BRITISH COLUMBIA. THE GFS EVEN PUSHES THE DRY PATTERN INTO NEXT WEEK...SHADES OF OCTOBER. OFFSHORE FLOW CONTINUES THROUGH THE WEEK BUT ISN'T STRONG
ENOUGH TO PRECLUDE FOG FORMATION

THIS MORNINGS FOG HAS BURNED OFF IN ALL AREAS EXCEPT THE VERY SOUTH PART OF PUGET SOUND AND THE OLYMPIA AREA. DEWPOINTS IN THIS MORNING'S FOGGY AREAS ARE STILL RUNNING A LITTLE HIGHER THAN FORECAST BY MOS. WITH MOST LOWS MONDAY MORNING FORECAST TO BE BELOW FREEZING THERE IS A GOOD CHANCE THAT A GOOD BIT OF THE LOW LEVEL MOISTURE WILL SUBLIMATE OUT AS FROST...THUS REDUCING THE DENSITY AND COVERAGE OF MORNING FOG. WILL SIT ON THE FENCE AND WORD FORECASTS THE NEXT TWO DAYS AS AREAS OF FOG FOLLOWED BY AFTERNOON AND EVENING CLEARING. FROM WEDNESDAY ON...WITH LOWS CLIMBING BACK INTO THE 30S...WILL INCREASE THE COVERAGE OF FOG AND MENTION ONLY PARTIAL CLEARING. MAX TEMPS
COULD BE A BIT COOL GIVEN THAT FREEZING LEVELS SHOOT UP TO 8000 FEET ON MONDAY AND NEAR 10000 FEET OVER THE OLYMPICS ON TUESDAY. HOWEVER...FOG COVERAGE AND PERSISTANCE WILL STRONGLY AFFECT MAX TEMPS SO WILL STICK CLOSE TO AVN MOS. **THE LAST FACTOR IS THE POTENTIAL FOR AIR STAGNATION. THE INVERSION WILL REMAIN STRONG AND VENTILATION RATHER WEAK...BUT FOG CAN HINDER THE INCREASE IN POLLUTANTS. AN AIR STAGNATION WATCH OR ADVISORY MAY BE NECESSARY BY MIDWEEK DEPENDING
UPON HOW MUCH FOG DEVELOPS**. KAM
UIL 0000 SEA 0000 OLM 0000

.SEW...NONE.
.KATX...VCP32/CSR32...OPERATIONAL.

Summary

- Find reliable products that you understand and trust.
- Start with the synoptic scale, then work down to urban scales.
- Establish a good working relationship with local NWS forecasters and local university meteorology departments.
- Keep a good archive of weather images.

- Next step – Case Studies
- Questions